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Robert P. Sharp
California Institute of Technology

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The southern coast of Alaska is one of the world's most accessible areas of large glaciers. As a result, the lower parts of Alaskan coastal glaciers have been extensively observed and studied since they first became known to the modern world through the exploratory voyages of Cook, Vancouver, La Pérouse, and others in the late eighteenth century. However, the high, rugged, snow- and ice-bound mountains from which these ice streams flow are difficult of access, and information on the gathering grounds of these glaciers is correspondingly scanty.

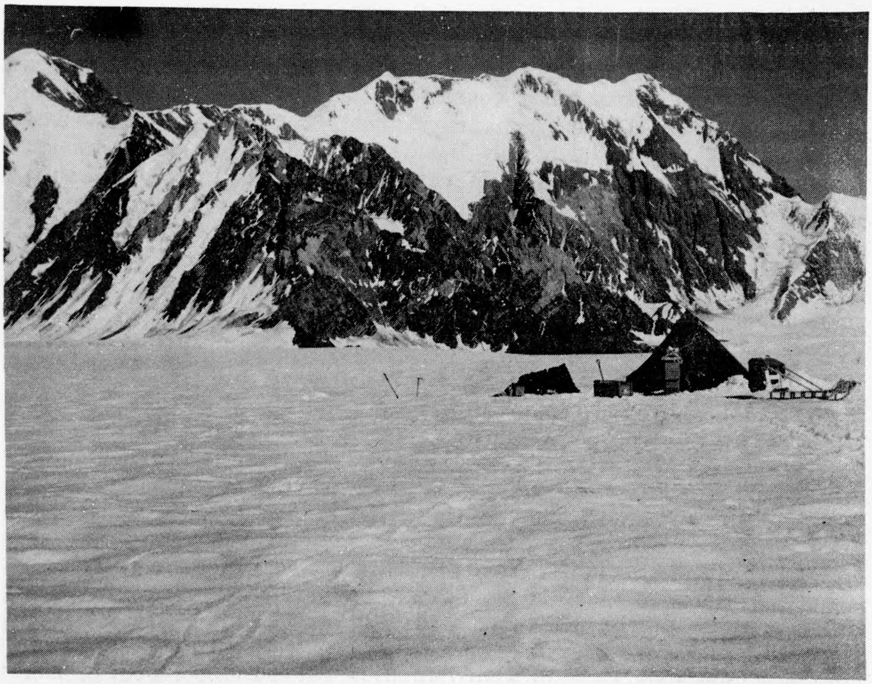

Fig. 1. Glaciological research camp near eastern edge of Seward Ice Field looking east. Mt. Vancouver (15,700 feet) in background.

In 1948 "Project Snow Cornice" sponsored by the Arctic Institute of North America and directed by Walter A. Wood offered opportunity for investigating the nourishment areas of glaciers along the Alaska-Yukon border. A contract with the Office of Naval Research afforded the means of capitalizing on this opportunity, and a research station was established near the eastern edge of the great Seward Ice Field in the heart of the St. Elias Range. Although this station is actually in Canada

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Robert P. Sharp, professor of geomorphology at the California Institute of Technology, received his B.S. and M.S. degrees (1934 and 1935) from that institution and his A.M. and Ph.D. from Harvard University. He taught at both the Universities of Illinois and Minnesota. During the war he served with the Army Air Force in their Arctic, Desert, and Tropic Information Center. He has been teaching since 1947 in the field of physical geology at the California Institute of Technology.

(60° 23′ N., 139° 53′ W.), it is most easily reached by a northward plane flight of about 60 miles from Yakutat, Alaska, and the Seward-Malaspina glacier systems lie partly in Canada and partly in Alaska. These glacier studies are still largely in the information-gathering stage, and the work of 1948 served principally to lay the ground for more extensive investigations to be made in the summer of 1949.

A major objective of most glacier studies is to determine the state of health of the ice body. This is done by determining the difference between income, chiefly in the form of snow, and expenditures, largely by melting. In 1948, at elevation 5700 feet on Seward Ice Field, the excess of accumulation over wastage for the year 1946-1947 was found to be about 35 inches of firn, a coarse granular snow of density 0.45 or greater. This can be more accurately expressed as equivalent to 17.5 to 18 inches of water. Preliminary figures indicate the excess accumulation for 1947-1948 to be about 23.5 inches of water. Seward Glacier flows 20 miles southward from this icefield through a steep canyon and spreads out on a broad flat coastal plain close to sea level to become part of the great Malaspina piedmont sheet. In this lower area wastage far exceeds accumulation, so the Seward draws on its accumulated reserve in the ice field. If this reserve is not sufficient to meet total expenditures, the glacier runs a deficit and retrenches by recession. If the accumulated reserves surpass expenditures, the glacier, like an optimistic businessman, expands. Total wastage of the Seward Glacier system has not yet been determined, so the balance sheet cannot be completed. That is one of the tasks set for 1949. Most glacier systems throughout the world are currently running a deficit, and this one will probably prove no exception.

The present state of health and immediate past history of glaciers have several significant aspects. First, a glacier is a relatively efficient, automatic weather observer, and most of them are located in relatively remote areas where weather stations are not maintained and not likely to be established. If we learn how to interrogate them properly, glaciers can tell a lot about weather conditions in remote areas for a decade or two in the past. Second, the ultimate cause of "ice ages" is still a matter of speculation. Some theories require alternate periods of glaciation in the Northern and Southern Hemispheres. If these theories are sound, it would be reasonable to expect present glaciers in these hemispheres to be approximately one-half cycle out of phase. Such does not seem to be the case, but more information is needed. The Seward Ice Field is but one reference point in an extended investigation of such matters being carried out under auspices of the American Geographical Society. It is hoped that Navy aerologists will be able to join the project in 1949 to make micrometeorological studies on the Seward Ice Field. These will be directed toward determining the relative influence of radiation, conduction, convection, and condensation on wastage.

Temperature measurements at various depths in the firn by means of thermohms and a Wheatstone bridge, loaned by the Bureau of Standards, show the Seward Ice Field to be a "temperate" glacier; that is, one which is at its pressure-melting temperature throughout, except for a thin surficial crust chilled to subfreezing temperatures in winter. Refreezing of downward percolating meltwater in the spring is thought to be largely responsible for development and growth of the horizontal ice bands and vertical pipes of coarsely crystalline ice in the firn. In mid-summer after the winter's chilled layer has been destroyed, the amount of meltwater percolating through the granular firn is surprisingly

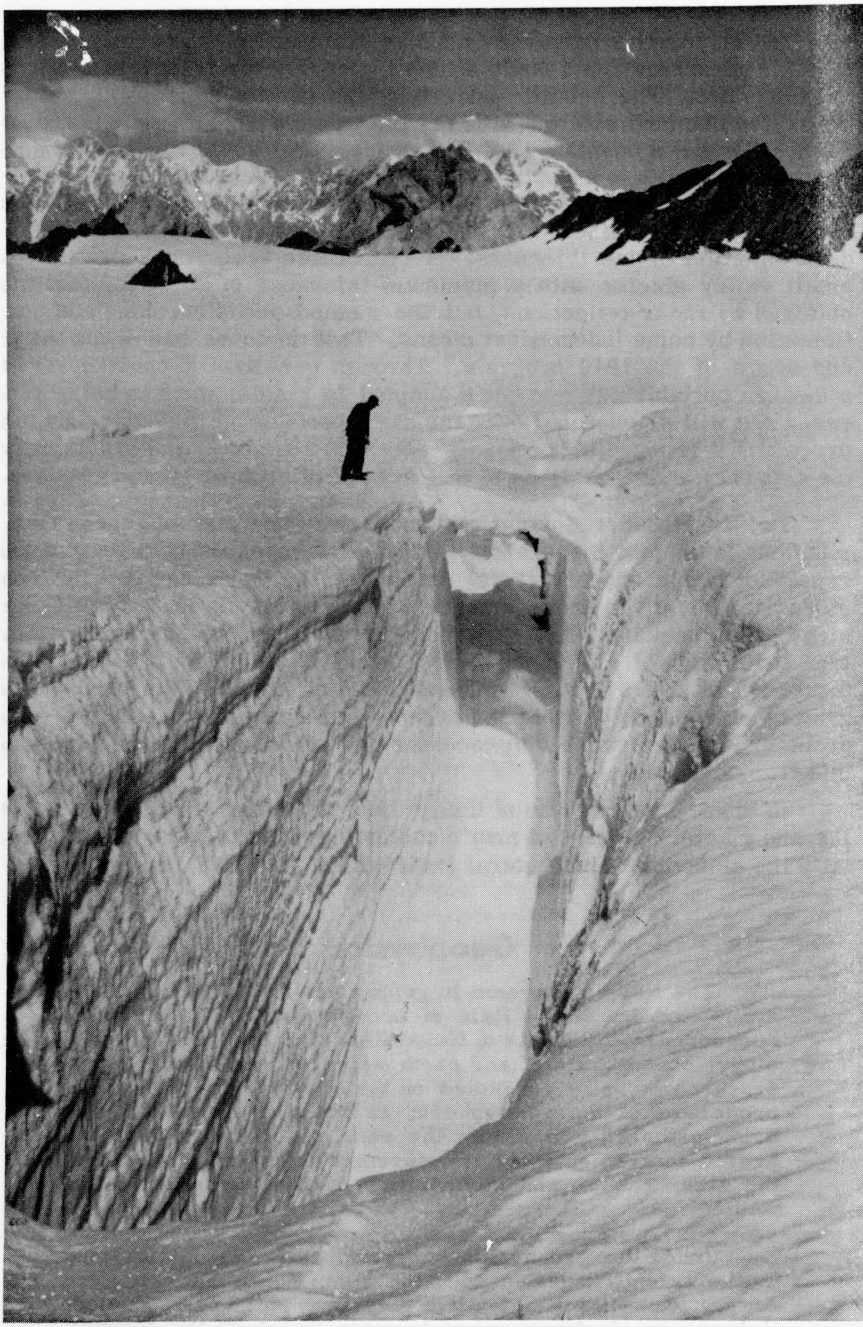

Fig. 2. Crevasses expose the third dimension and reveal numerous horizontal ice bands in the firn.

large. This water accumulates at a depth of 65 to 70 feet to form a water table. Thermal borings first suggested this, and it was later confirmed by finding standing water in crevasses at that level. The winter's chilled layer probably does not penetrate much deeper than 50 to 60 feet, so the intriguing thought arises that a well drilled into the Seward Ice Field would probably yield water even in the dead of winter when all other sources are frozen.

In 1948, parties from the Canadian National Research Council used seismic apparatus and a sonic echo-ranging set in attempts to measure ice thickness. The seismic operation was not too successful, but one reflection obtained within 3 miles of the eastern edge of the Seward Ice Field indicated a possible 1600 feet of ice. The sonic ranging set gave promising results to a depth of about 450 feet. This would seem to be a useful method in thin ice, but its ultimate possibilities and limitations are as yet undetermined. An attempt was also made to use radar for determination of ice thickness. A reasonable transverse profile of a small valley glacier with a maximum thickness of about 700 feet was obtained by radar reflections, but the method needs checking and confirmation by some independent means. That is to be one of the major endeavors of the 1949 program. Through generous support by ONR, a modern portable seismic outfit adapted to glacier work is being procured and will be operated over the same profiles as the radar. By this procedure it is hoped to "prove out" the radar soundings and to determine the accuracy and limitations of that method of probing glaciers.

Dr. Henri Bader, formerly of the Swiss Snow and Avalanche Commission, is to join the project in 1949 and is planning a program of crystallographic and structural studies on the Malaspina Glacier west of Yakutat Bay. It is known that ice starting as tiny delicate snow flakes high in the mountains ends up as large crystals several inches in diameter at the edge of Malaspina Glacier about 60 miles south and perhaps thousands of years later. In the process of flowage, the ice crystals grow in size and develop a preferred crystallographic orientation. The problem is to determine the processes and conditions which bring about this transformation.

In brief then, the aim of this project is to learn more about snow, ice, and glaciers as part of man's continuing effort to comprehend more fully the elements of his natural environment.

Geophysics

The Navy's program in geophysics is still young. It is a new and important field of investigation. The program sponsored by the Office of Naval Research includes meteorology, oceanography, and earth sciences. In meteorology, research is being conducted on the physical processes and properties of the atmosphere; in oceanography, data are being gathered concerning the sea, ocean floors, and improved instruments for measurements; in earth sciences, the size, shape, and composition of the earth are being studied.

Under the geophysics program, ONR has participated in the scientific phases of: the Finn Ronne Expedition to Antarctica; Bikini Scientific Resurvey of 1947; Project Volcano, or air-borne magnetometer survey of the Aleutian arc and Northern Marshall Islands; Operation Highjump to Antarctica; seismic and microbarometric observations of the Helgoland demolition, or Project Big Bang; Project Cima, or the coordinated investigations of Micronesian anthropology, and the Naval medical section accompanying the University of California African expedition.